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An Aluminum Hydrate Plant

Chemical Engineers' First Manufacturing Scale Project

By PHILLIP J. BORNHORST, '28

Chemical engineering, in some peoples' minds, is thought to deal mostly with chemistry, but of the two words *chemical engineering*, the word *chemical* is the adjective and *engineering* the noun. Therefore, chemical engineering is engineering and not chemistry. A chemical engineer must have a knowledge of engineering drawing, machine, plant, and mill building design, etc., as well as a knowledge of chemistry. He must recognize that the problem of any industry is to *meet the market demand and make a profit*. His study of an industry may be divided into three parts:

1. Problems of the market and economic demand.
2. Problems of the chemistry.
3. Problems of engineering.

Therefore, chemical engineering may be defined as that branch of engineering which applies chemical and engineering principles to manufacturing for the benefit of humanity.

During the twenty years of existence of Chemical Engineering at the Ohio State University, the present Chemical Engineering class of 1928 is the first one to actually set up and run a plant on a manufacturing scale. In the years past the classes have worked out similar problems, but on paper and in theory, rather than by actual operation test, for which until the present year, there have been no facilities. Aside from the general chemical and engineering principles of operation and design to be taught by this manufacturing scale plant, it served the immediate purpose of preparing the students for Engineering Drawing 702, the course in Plant Design Work.

In the following discussion, an account will be given of how the present Chemical Engineering class, acting as the technical staff of a large plant with the instructoral staff of the department as the Managing Staff of the plant, applied chemical and engineering principles to manufacturing. After working out the problem "Make 250 grams of a C. P. Chemical at a profit" which was introductory to the main problem, the class was given the main problem. *Shall we continue to buy on the open market, or shall we make ourselves 20 tons per day of Light Aluminum Hydrate.* Light aluminum hydrate was selected for the problem for manufacturing purposes, since aluminum hydrate is not so important industrially, as to distract the attention of the class, yet at the same time it is important as a clarifier in the chemical industries. Now it is necessary to keep in mind that this plant must be operated to make a product which will meet the market

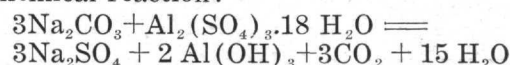
demand (light aluminum hydrate) and at the same time make a profit.

Therefore, the first step in working toward the manufacturing scale plant was Part I—*Lowest Possible Cost*. This was a problem to be solved by consulting chemical literature, and by calculations using the following conditions in solving:

1. Market Quotations to be taken from Oil, Paint, and Drug Reporter, Oct. 17, 1927.
2. No by-products to be considered.
3. Operation Cost not included.
4. 100% yield and Face Purity of Materials.
5. Raw materials to be:

- (a) Soda Ash (Na_2CO_3) 58%
- (b) Alum ($\text{Al}_2(\text{SO}_4)_3 \cdot 18 \text{H}_2\text{O}$)

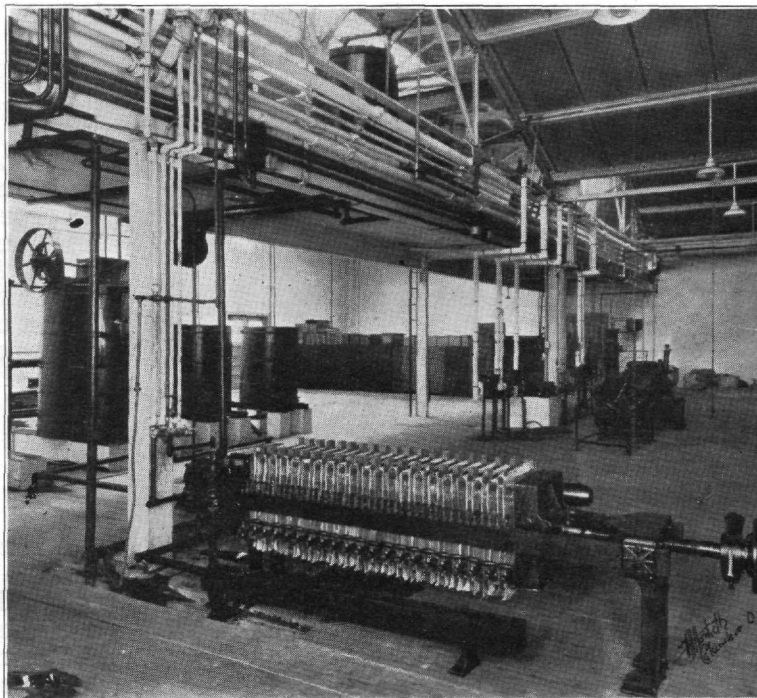
6. Chemical reaction:



The following Quotations were used:

Soda Ash (Na_2CO_3) 58% Light, car-load lots bags, 100 lbs.	\$1.325
Alum $\text{Al}_2(\text{SO}_4)_3 \cdot 18 \text{H}_2\text{O}$ Commercial 100 lbs.	\$1.41
Aluminum Hydrate ($\text{Al}(\text{OH})_3$) barrels per lb.	\$0.16

Under the stipulations set down it was found that the lowest possible cost was \$3492 by making it ourselves and that \$2908 margin was left for manufacturing charges and profit.



Aluminum Hydrate Lab. Plant Interior

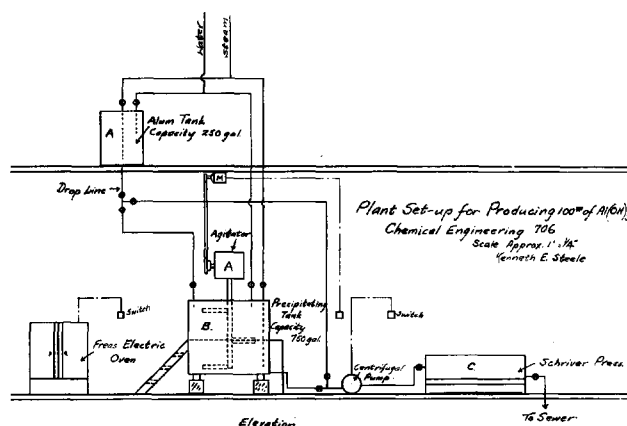
Finding conditions very favorable financially, the next step was to run a laboratory yield and see how efficient the stoichiometrical relations would hold. Therefore Part II, *Lowest Probable Cost* was undertaken. Yields were produced in the Industrial and Chemical Engineering laboratories on the basis of 50 to 100 grams. Results showed that the lowest probable cost per 20 tons per day, "making ourselves" would be in the neighborhood of \$4460 with a margin of \$1940 a day. Certain fundamental principles were developed in this part, namely that of testing for the end point of a reaction and that of washing and filtering a precipitate which is one of the most difficult to wash and filter. Apparent Gravities were run on the products and were found to range from .132 to as high as .5, so that the making of a "Light" product was clearly feasible.

Proving to ourselves by laboratory tests of Part II (Yield) that the aluminum hydrate could be made light by actual run at an apparent profit to ourselves, it followed that a sketch was required of a 20 ton per day plant for making light aluminum hydrate; the plant sketches to be preliminary to the final design. The sketches were made by each member of the class based on his own results of Part II (Yield). These sketches included plan and elevation layouts, from which missing gaps in information were at once discovered.

Now it became necessary to conduct a laboratory research and determine the best possible conditions under which the light product could be made. The laboratory and other researches were planned and conducted so that each member of the class (staff) had a different set of conditions to work with. This was accomplished by dividing the laboratory section into two groups and appointing a foreman over each group. The foreman's duty was to assign the conditions under which the various men were to work and then make a report of all the information obtained. The idea of two groups was to use the two set of conditions, one the addition of alum to Soda Ash and the other the addition of Soda Ash to Alum. In this way the best possible set of conditions for the time available were obtained for making light aluminum hydrate. H. E. Wright and W. C. Barnett were foremen of the two groups respectively. H. B. Grimm obtained the lightest product by apparent gravity test with the following set of conditions making 115 grams.

1. Order of addition Alum to Soda Ash
2. Concentration of Alum Solution 80 grams per 100 cc H₂O
3. Concentration of Soda Ash 15 grams per 100 cc H₂O
4. Temperatures throughout 35°C ± 5°C
5. Digestion 30 minutes
6. Wash Water 2500 cc
7. Yield 115 grams based on 100 gram calculations
8. Moisture in cake .82%
9. Apparent Gravity .135

The precipitate contained a large amount of Na₂SO₄ which was washed out. The BaCl₂ test



was used for determining freedom from Na₂SO₄ in the product being washed.

Now, with all of the data for the making of light aluminum hydrate, apparently necessary for plant design, the next step was to design a plant to manufacture the product. The stipulations made by the Managing Staff were as follows:

1. 100 lb. plant to be designed to discern large scale manufacturing behavior and to run out the kinks before designing actual plant.
2. Where possible the equipment set up in the machinery laboratory should be used.
3. Sketch is to show both plan and elevation.
4. Complete working schedule to be made such that workmen can follow directions.
5. Bill of material to accompany report.
6. Plant to operate for a month or year (indefinite time).
7. Conditions in plant to be made same as those determined by lab. research above given.
8. Complete log of all operations to be kept.

While the original problem stipulated 20 tons, 100 lbs. were used in place of 20 tons due to the fact that it would be unwise expenditure to build a plant and to manufacture 20 tons of light aluminum hydrate in this experimental plant. Therefore, the logical thing to do was to take a small factor of this whole, work it out, make a manufacturing run and then revise the preliminary design of the 20 ton plant by comparing it to this 100 lb. plant.

Before the final design was worked out, however, a preliminary survey was made of the equipment available in the machinery laboratory, such as dryers, tanks, piping, pumps, presses, etc. Measurements were taken of all the equipment, which, it was thought, might be used in designing the plant. With this equipment in mind and using the set of conditions determined in the laboratory and noted above, the design of the plant was laid out and all equipment designed to take care of making 100 lbs. of light aluminum hydrate at one time.

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AG NOTE

A rooster by perseverance rolled an ostrich egg into the chicken yard. He called the hens to him, and said:

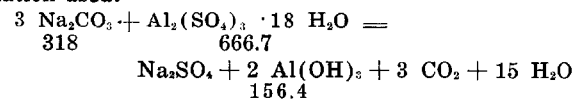
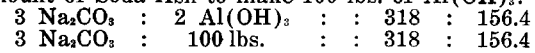
"I am not casting any insinuations, and I am not reproaching any of you hens, but I do want you to see what is being done in other quarters." —Auburn Engineer.

AN ALUMINUM HYDRATE PLANT

(Continued from Page 12)

Calculations for 100 lb. Plant:

Equation used:

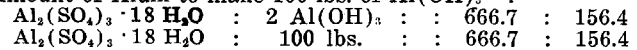
100 lbs. of Al(OH)_3 to be madeAmount of Soda Ash to make 100 lbs. of Al(OH)_3 :

$$(\text{Na}_2\text{CO}_3) = \frac{100 \times 318}{156.7}$$

Since 58% Soda Ash is 58% Na_2O , Purity is 99.2% for Na_2CO_3

Therefore

$$(\text{Na}_2\text{CO}_3) = \frac{100 \times 318}{156.7 \times .992} = 204.9 \text{ lbs. req'd}$$

Amount of Alum to make 100 lbs. of Al(OH)_3 :

$$(\text{Al}_2(\text{SO}_4)_3 \cdot 18 \text{ H}_2\text{O}) = \frac{100 \times 666.7}{156.4} = 426.3 \text{ lbs. req'd}$$

Amount of water to dissolve the Alum:

$$426.3 \text{ lbs.} \times 454 \text{ grams} \times 100 \text{ cc.} \times 1 \text{ gram} = 8.52 \text{ cu.ft.}$$

$$80 \text{ grams (conc.)} \times 454 \text{ grams} \times 62.5 \text{ lbs.}$$

Amount of water to dissolve Soda Ash:

$$204.9 \text{ lbs.} \times 454 \text{ grams} \times 100 \text{ cc.} \times 1 \text{ gram} = 21.8 \text{ cu.ft.}$$

$$15 \text{ grams (conc.)} \times 454 \text{ grams} \times 62.5 \text{ lbs.}$$

Size of Tank A for making up Alum Solution:

Use Tank A on second floor—Size 32" dia. 46" height.

$$\text{Volume of Tank A} = \pi \left(\frac{4}{3} \right)^2 \times 3 \frac{5}{6} = 21.26 \text{ cu. ft.}$$

Size of Tank B for making up Soda Ash solution and then precipitating Aluminum Hydrate by allowing Alum solution to run into same Tank B—Size 56" dia.—70" height.

$$\text{Volume} = \pi (7/3)^2 \times 5 \frac{5}{6} = 102 \text{ cu. ft.}$$

Volume that would be placed in Tank B

$$8.52 (\text{Alum Sol.}) + 21.8 (\text{Soda Ash Sol.}) = 30.2 \text{ cu. ft.}$$

This would allow 70 cu. ft. or approx. 66% vol. for foaming. This was thought to be ample and safe for precipitation, but must be ascertained by small scale manufacturing run, which after all is our purpose to uncover unknown information.

Size of Filter Presses and number to install:

Shrieffer's press in lab. has 16 chambers—Cap. 1.7 cu. ft.

Specific gravity of Al(OH)_3 —2.42.Specific gravity of mixture of Al(OH)_3 (18%) and H_2O (82%)

$$.82 \times 1 = .82$$

$$.18 \times 2.42 = .436$$

$$\text{Specific gravity of mixture } .82 + .436 = 1.25$$

(Continued on Page 24)

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ALUMINUM HYDRATE

(Continued from Page 22)

Weight of mixture we would have:

18% equals 100 lbs. of $\text{Al}(\text{OH})_3$

Therefore 100% equals 555 lbs. of mixture (Slurry)

555.0

= 7.14 cu. ft. vol. of cakes.

62.5 x 1.25

7.14

= 4.2 Say 4 filter presses

1.7

Size of Oven for drying:

Freas Oven in lab.—40" x 40" x 36"—Vol. 33.3 cu. ft.

Since we need only 6.8 cu. ft. (vol. of 4 presses) this oven is sufficiently large.

Size of Pump:

21 cu. ft. (Slurry to be filtered) x 62.5 lbs. x 1.25

= 1.58 gal. to
be pumped

1.25 x 8.3 (lbs. per gallon)

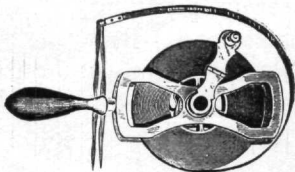
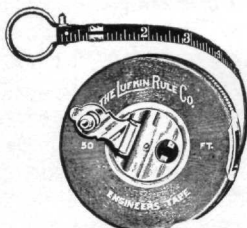
Since lab. contains a 120 gal. per min. pump (Centrifugal) we shall use this pump.

*Final Data compiled from all reports relative to
100 lb. Experiment in Machinery Laboratory.*

100 lb. batch to be made as per method decided upon by class after investigation in laboratory, that is:

Class	{	372 lbs. of alum in 465 lbs. of water.
		179 lbs. of soda ash in 1194 lbs. of water.
		Temperature of precipitation to be 35°C.
Avg.	{	End point to show slight excess alum and
to be slightly acid to litmus.		

(This article will be concluded in our next issue.)

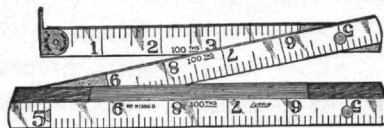


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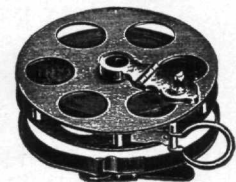
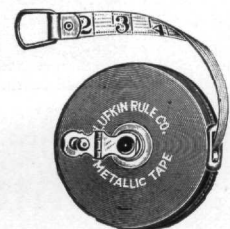
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